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ABSTRACT

While the logic of science serves as the methodological framework for psychological research, its particular merit for educational evaluation has yet to filter into practical application. The logic of science provides a strategy for evaluating large and complex educational treatments that is a useful guide to program development and improvement. This paper explicates a method of scientific inquiry applicable to the formative evaluation of educational programs and, in so doing, illuminates an artificial distinction between the ways in which concepts are validated in science and education. (Author)

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While the logic of science serves as the methodological framework for psychological research, its particular merit for program development and evaluation has yet to filter into practical application. The logic of science offers a basic strategy that can be used as a comprehensive guide to the formative evaluation of large and complex educational programs. The purpose of this paper is to explicate the logic and method of scientific inquiry traditional to psychological research, but applicable to the development and evaluation of educational programs.

The logic of science depicts educational programs as a network of instructional concepts, intervening constructs, and observable data so that a hierarchy from perceptual (observable) to conceptual, subordinate to superordinate, specific to abstract is built with the most specific and reliable data subordinate and the least specific and least reliable concepts superordinate. The continuum is basic to scientific inquiry whether in the physical sciences, humanities or education. The researcher studies observables as basic datum from which he builds higher order constructs and concepts. Figure 1 illustrates the organization of a mathematics curriculum which mirrors the scientific mode of inquiry upon which it is based.

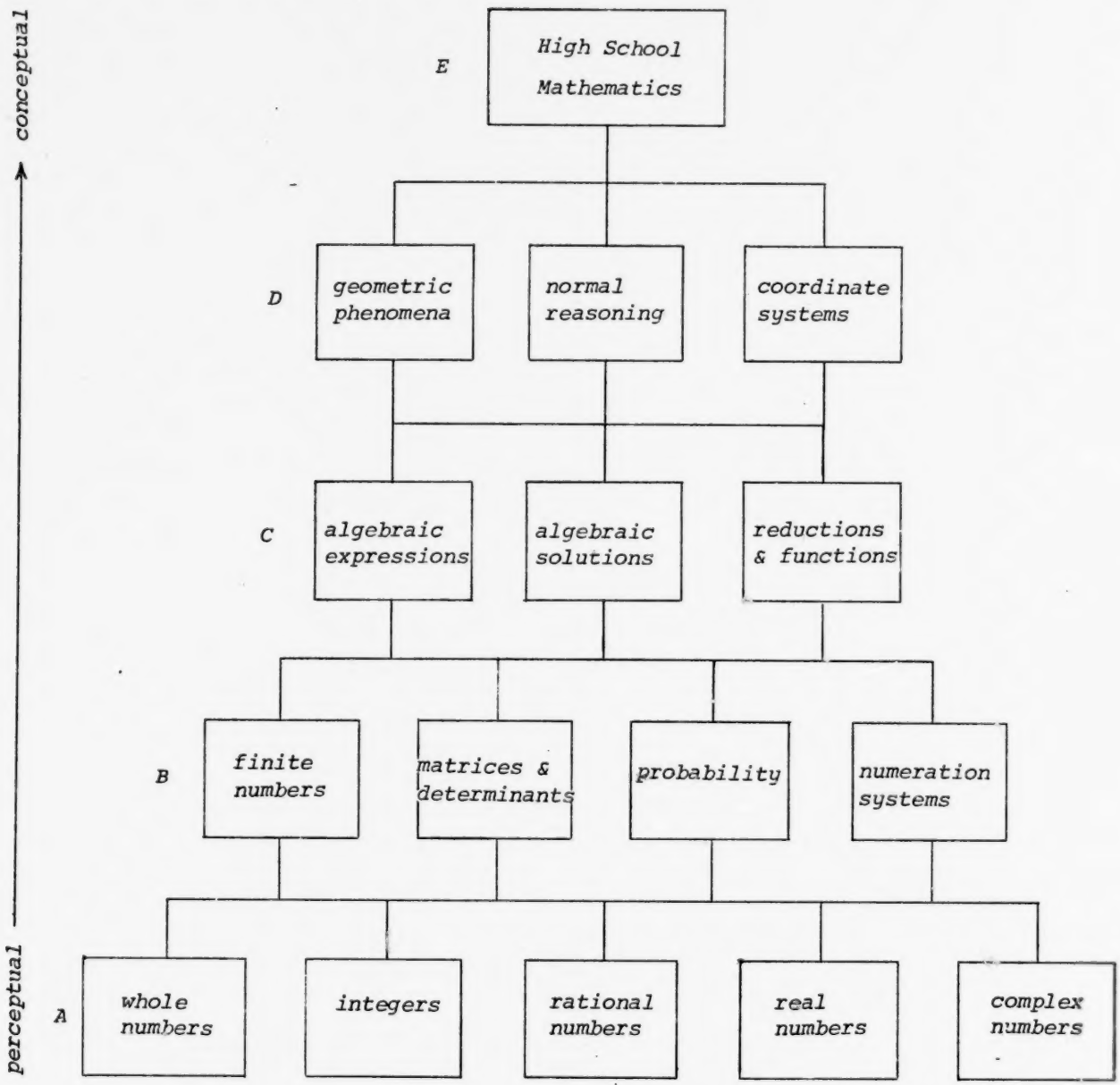


Figure 1. Hierarchical conceptualization of a mathematics curriculum

In a well-defined curriculum, movement from the perceptual to the conceptual is well mapped with passages between concepts short and reliable so as to create the maximum probability of the proposition, if A then B. The reliability of a passage is expressed as the ratio of pupils who achieve learning set A to those who obtain the superordinate set, B. For curricula that are well developed even the most hierarchical of concepts may be closely tied to observables through several intermediate concepts which differ from observables in only small degrees of abstraction. Curricula patterned after Gagne's work (1965) serve as practical examples of the scientific model.

Large and complex educational programs, however, are rarely so tight or so logical. For an educational program, passages from observables to the intermediate constructs may be short and reliable, while passages from the intermediate to the hierarchical concepts are likely to be long and circuitous. Because hierarchical concepts are tenuous, their development and evaluation is difficult. For large, complex educational programs a model based upon methods of scientific inquiry may be more appropriate for formative program improvements than traditional evaluation schemes. The following discussion serves to explicate a proposed methodology for formative evaluation after which an example will illustrate its use in a large and complex educational program.

A definition of "concept." Although program developers and evaluators use the word "concept" almost daily, its use is often devoid of explicit meaning. Psychologists have added to the ambiguity by often using the words "concept" and "construct" interchangeably.

Concepts themselves vary so that some may be so abstract as to elicit from memory little or no observable data, such as the concept of "meaning" itself. Or they may be more intuitive, such as the concept of "man" or "tree." Or, still yet, they may be burgeoning with rational and empirical relationships such as the concept "number." Our most hierarchical concepts for complex educational programs are usually intuitive and often coincide with the theme or purpose of a particular program such as "personalized education for teachers," "individualized instruction for the gifted," "remedial instruction for the disadvantaged," all of which imply underlying behaviors for teachers, the gifted, and the disadvantaged which are expected to change as a function of some treatment. Often the most hierarchical concept (personalization, individualization, remediation) is the only concept with which the program developer begins his work. While the curriculum developer works with concepts that have known relationships within and between substantive disciplines, the program developer faces a lack of specificity and a need for a viable plan which can link superordinate program concepts and constructs with observable behavioral data.

To the developer a distinction between concept and construct is useful. On a continuum of superordination constructs lie between concepts and observables and when quantified for measurement purposes are referred to as intervening variables. Constructs are defined in terms of their antecedents which comprise observable data and are dependent on them for their meaning. Concepts however are inferred variables that may or may not have clear empirical antecedents. A concept without clear empirical antecedents is a hypothetical construct (HC). HC's are not reducible to that of their

antecedents and therefore a degree of error must be expected in passing to the inferred concept from its hypothesized antecedents.

The term "superordinate" has been used by Rozeboom (1956) to denote a continuum of HC's which vary in degrees of uncertainty. The HC of a program is its most uncertain concept. The developer works to build into the program antecedents which provide clear and direct relationships to its superordinate concept while the evaluator focuses on the extent to which these relationships are in fact clear and direct. At least three degrees of HC uncertainty may be identified.

Degree of HC uncertainty. The least uncertain of these is an HC for which there are specified antecedents whose prediction of higher order concepts is uncertain. The HC is positioned a step above an array of more specific intervening constructs which could serve as antecedents when their relationship to the HC is empirically confirmed. Figure 2 depicts attitude as an intervening construct (IC), intermediate in superordination to individualized learning and observed program inputs. The HC takes on meaning with the specification of an IC as one of its components. Many such IC's are needed to operationally define an HC.

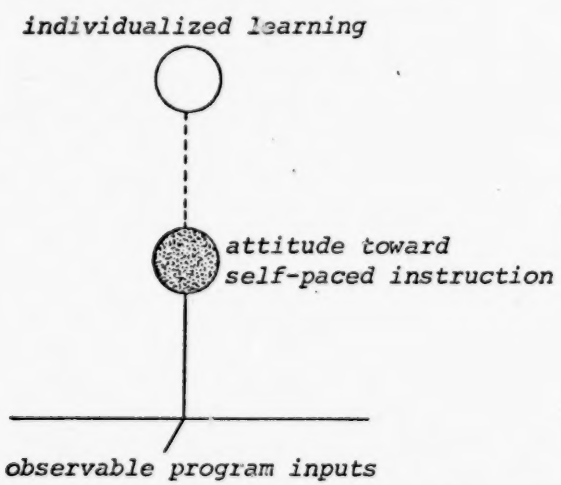


Figure 2 Intervening construct linking an observable program input to a hypothetical program concept

A second more uncertain HC is one in which its constituent properties exist separately, but whose joint existence is uncertain. The network becomes more complex with the insertion of additional IC's whose relationship to HC is still uncertain. Figure 3 represents an expanded network with motivation and two subsidiary constructs in a hypothesized relationship to HC.

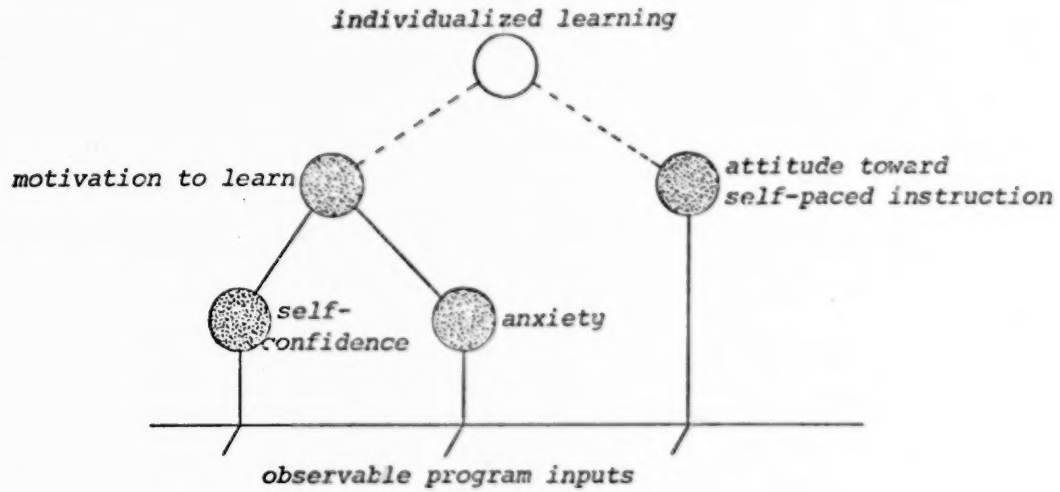


Figure 3 Expanded network of intervening constructs linking observable program inputs to a hypothetical program concept

Although attitude toward instruction and motivation have been well documented as constructs their hypothesized joint occurrence in relation to individualized learning is specific to the nature of the program being studied. The task of supporting or refuting these constructs as components of individualized learning via correlation or experimental manipulation is a primary task for program evaluation.

The third and most uncertain type of HC is one in which at least one antecedent construct assumes a theoretical relationship which as yet

has not been established and therefore one in which the connection between construct and concept is in a highly tenuous state. Program developers hypothesize a general relationship neither confirmed nor refuted by current theory. If the hypothesized relation is critical to the HC, i.e., not simply an alternative explanation of it, program evaluation must posit a theory that can account for the critical relationship. This may well be the case in Figure 3, hence the broken lines between constructs and concept. A program built on many such hypothetical relationships becomes a heuristic for research more than a program that is expected to engender observable behavioral outcomes. Tenuous relationships posed as alternative hypotheses, however, provide important additions to the network as rival hypotheses for follow-up exploration.

Passage of data to orderly knowledge. The program developer either consciously or unconsciously posits bonds between constructs and concepts during the development process. Northrop (1946) has called these bonds "epistemic correlations," Margeneau (1950) "passages" and Morris (1946) "syntax" vis a vis "semantics," while the hard scientist speaks of "rules" or "laws of correspondence." The accuracy of prediction that is connoted from "rule" or "law" might be less appropriate for education than for the hard sciences where the reliability of measurements is often sufficient to warrant their use. Northrop's and Margeneau's terms may be more helpful in that a developer should hypothesize links between constructs and concepts that connect the empirical and hypothetical components of a program. Several kinds of passages are possible.

The most uncertain passage is often the result of endowing a concept with passages to and from constructs that are logical rather than behavioral.

A program to personalize the education of teachers might be described, for example, with "assessment," "individualized instruction," and "feedback" components which in themselves are descriptors that, although organize the program, do little to behaviorally define it. If "personalized" teachers act differently than other teachers, the program developer needs to know the behaviors that are prerequisite to or correlated with the HC which underlies the program, e.g., effective teaching. While the program proposal may specify assessment, individualized instruction, and feedback as program components, the developer must posit the importance of anxiety in relation to assessment, cognitive style in relation to individualized instruction and openness in relation to feedback. After psychological constructs are specified, the evaluator can determine whether or not feedback, assessment, and individualized instruction in their proposed form are congruent with and in fact engender the desired terminal behavior. Categorical descriptors of a program fail to define the behavioral underpinnings of a concept and often serve as "black" boxes which mask a plethora of behaviors which the developer needs to identify in positing passages to the HC.

A more fruitful approach to positing and defining concepts is to determine a sequence of behaviors that is intermediate to terminal behaviors. After reviewing a repertoire of behaviors that are related to HC and the intercorrelations that might be expected among them, the program developer specifies that y is likely to be a function of $x_1 \ldots x_n$; where $x_1 \ldots x_n$ are observed program inputs and y an intervening variable. The evaluator might posit causal connections between x_1, x_2, x_3 leading to y or a hierarchical arrangement in which each antecedent directly relates to y as in Figure 4.

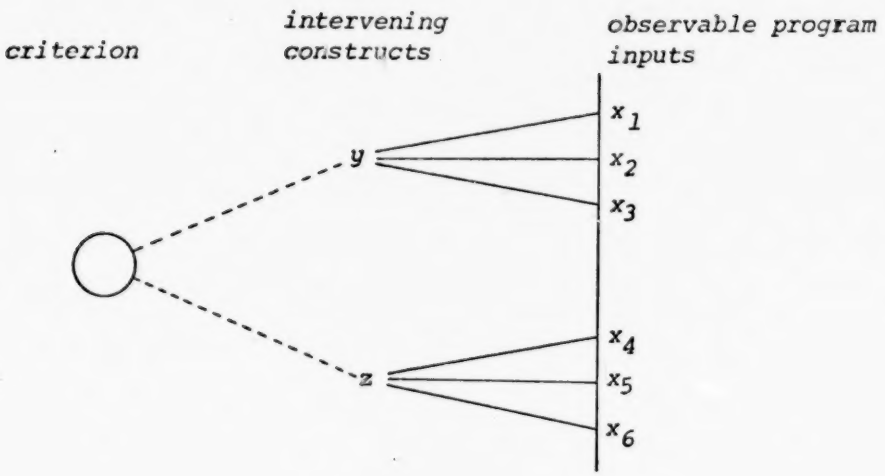


Figure 4 Intervening constructs multiply linked to observable program inputs

Like data are grouped under a single intervening variable in order to build the most parsimonious network. Intervening constructs are related to observed data beneath it and hypothetically to the concepts above it.

Program evaluation substantiates intervening constructs by confirming passages to and from them with correlational techniques. Correlations and regression equations are calculated to define the relationship between observable data and intervening constructs. Greater than chance correlations are expected between passages $x_1 \ldots x_3$ and y and $x_4 \ldots x_6$ and z. These correlations confirm the magnitude of the relationship while a prediction equation can mathematically describe the rate at which y increases relative to x (e.g., for every unit increase in x there is a two-unit increase in y so that when $x = 2$, $y = 4$, and when $x = 3$, $y = 5$). The developer is especially interested in relationships in which a small change in x coincides with a large change in y. For these variables small observable changes are likely to be most directly linked to the HC. If an intervening construct cannot be substantiated by any variables on the observable level, it should be removed from the network and from any proposed definition of HC.

Correlations are expected of less magnitude between y and HC, but if no relationship exists either the y construct and its observable counterparts must be dropped from the network or the program definition changed to reflect a more appropriate HC.

Verifying hypothetical concepts. Correlations allow us to pass from observables to the field of constructs and when used in reverse can verify the existence of hypothetical concepts. Reversals can be either trivial or non-trivial. A trivial reversal occurs when the path which led originally to the formation of a construct or concept is retraced as is illustrated with the dotted line between HC and W in Figure 5.

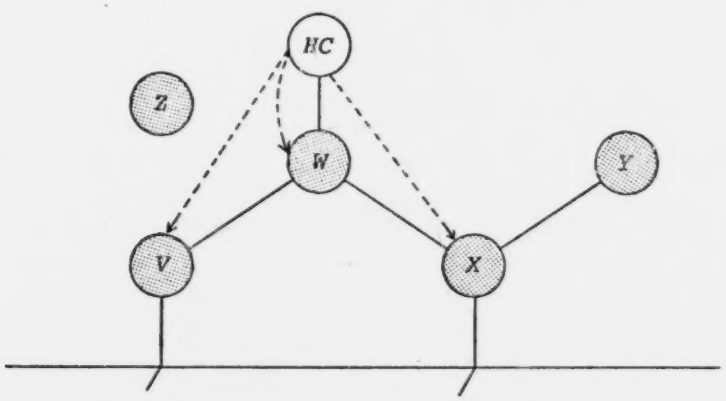


Figure 5 Trivial and non-trivial reversals in a network of intervening constructs

No new relationships are added to the definition of HC by the dotted line and HC becomes in effect the antecedent, W. A non-trivial reversal adds to HC by following a new path to other antecedents. HC becomes less tenuous as we substantiate relationships between it and other constructs. A relationship between HC and X is expected from a knowledge of relationships between X and W and between W and HC. The longer the path, the weaker the correlation is expected to be, so that X may account for only a portion

of the variance accounted for in HC and this must be less than that accounted for by W. Should the reverse occur the network is redrawn placing X in a superordinate position to W. The greater the distance to and from HC by any given loop, the more non-trivial the reversal. By establishing a complex of interrelationships more constructs are likely to share variance with HC and therefore become part of its definition.

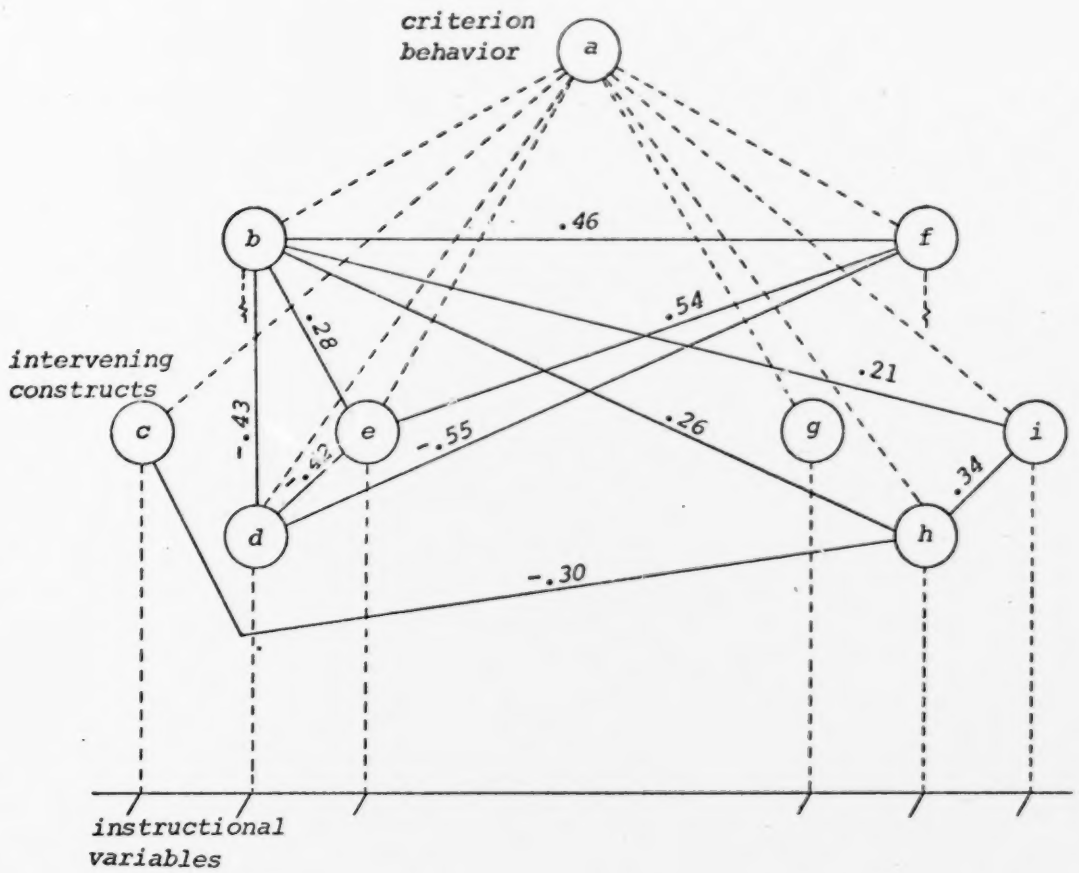
Constructs Y and Z suggest two other likely results. Y represents a peninsular construct which shares variance with X but with no other construct. Y has utility only with respect to a definition of X but may relate at some later time to additions in the network that may in turn relate to HC. Z on the other hand is an island construct that relates to no other construct. Z has potential whenever new constructs are added to the network, as does Y. Empirical relationships are posited among all constructs and concepts in the network. These empirical relationships account in part for changes in HC while defining and validating the program.

Correlational techniques, while helpful in the validation of intervening constructs, cannot alone constitute program evaluation. At some point the evaluator and developer seek passages between constructs and concepts that are causal. The program developer needs to learn whether, for example, high anxious participants might better be dropped from the program or perhaps receive a less threatening mode of assessment, whether one cognitive style might be more appropriate to individualized instruction than another, or whether the extent to which a participant is open to feedback dictates its value and efficiency. The evaluator seeks to specify an optimal value or permissible range of values for the intervening

constructs which relate to terminal behaviors. While Yee and Gage (1968) and Duncan (1966) suggest techniques for determining causal inferences from correlational data well worth studying, the evaluator may also have the opportunity to manipulate the instructional components of a program if only by using random or fortuitous fluctuations in program implementation. The time a program participant spends in a feedback session may, for example, differ as a function of the idiosyncracies of both program and participant. While some participants may receive brief feedback sessions due to tight class schedules others may receive lengthy sessions at more leisurely times, thereby altering the amount of feedback the program provides.

Variations such as these can be documented and studied as degrees of program implementation and constitute observable program inputs. By availing himself of fortuitous comparisons the evaluator moves from the observables (differing amounts of feedback) to an intervening construct (anxiety) and is now in a position to examine the relationship between anxiety and the hypothesized terminal behaviors using inferential techniques. Without traditional control groups and pre/post assessments the evaluator can often construct a sophisticated design which provides formative data to the developer and which evaluates the efficacy of moving from observed program inputs to hypothesized terminal behaviors through passages posited by the program. The evaluator begins by hypothesizing a network of constructs as depicted in Figure 6 and then measuring relationships between instructional variables and intervening constructs, and relating intervening constructs, in turn, to terminal behaviors. As evaluative data are obtained the network is rearranged to reflect confirmed relationships.

These relationships become a working document with which evaluator and developer begin revising and refining a program in order to bring about desired terminal behaviors.



KEY TO CONSTRUCTS

(a) criterion, e.g., pupil gain
(b) self-confidence
(c) anxiety
(d) efficiency
(e) reality orientation
(f) sociability
(g) openness to feedback
(h) attitude toward children
(i) attitude toward authority

_____ *confirmed relationships, $p < .05$*
------- *predicted relationships*

Figure 6 Hypothesized Network of Constructs Before Formative Evaluation of a Teacher Training Program

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